GREAT LAKES WATER LEVELS

COVER PHOTO –
Aerial view of the Prescott Bridge, crossing the St. Lawrence River, near Prescott, Ontario, Canada.

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Issued by the Water Resources Branch under the authority of the
HONOURABLE ARTHUR LAING, P.C., M.P., B.S.A., Minister of Northern Affairs and National Resources, 1964

FOREWORD

Water is becoming Canada's most valuable asset. It is already our most versatile mineral. Not only are the uses for water changing in character, but the needs for water are becoming paramount in ever widening areas of the country. Water used to be a regional problem, isolated in small areas. The need now reaches the proportions of river basins and entire lake systems. Water has become national in importance and will become – sooner than we think – a major concern to all of us on this continent. River basins may no longer be considered as isolated one from the other.

The present low water levels on the Great Lakes and their outlet rivers have brought the meaning of water to Canada into sharp focus.

Because the Great Lakes system is complex and the technological aspects of the situation difficult to grasp, considerable misunderstanding of the reasons for water level changes has arisen, especially the reasons for the present low levels.

The factor mainly responsible for these low levels is lack of snow and rain in the Great Lakes basin for the past three and a half years. Natural causes are simple, drastic, and show no concern for the needs of men.

According to data collected by Canada's Meteorological Branch, and the United States Weather Bureau, rain and snow during these past three and a half years have fallen short of normal by about four inches on the drainage basin of Lake Superior, and eight to twelve inches on the remainder of the Great Lakes basin. Periods of low precipitation are usually accompanied by higher evaporation and the combined effect of these drought conditions has compounded the water shortage.

Great Lakes water levels, their changes and trends, have been studied by engineers and scientists for many years. Much is already known about the subject by those with the professional responsibilities for dealing with it. But more should be known by Canadians whose work lies in other fields. All of us, no matter what our interests, are affected vitally by water *as* water and also by how it is managed to meet Canada's largest needs.

This booklet has been prepared to draw on some of this accumulated knowledge to answer, as simply as possible, some of the questions most often asked about what is happening to Great Lakes water levels.

Those who would like to have more detailed and technical data, are invited to write to the Water Resources Branch of the Department of Northern Affairs and National Resources in Ottawa.

James Bay
Attawapiskat R.
L. St. Joseph
Albany River
Ogoki R.
OGOKI DIVERSION
Kenogami R.
Lac Seul
Lake of the Woods
Lake Nipigon
LONG LAKE DIVERSION
ONTARIO
QUEBEC
Moose R.
Mattagami R.
Harricanaw R.
Nottaway R.
Rupert R.
PORT ARTHUR
FORT WILLIAM
LAKE SUPERIOR
CANADA
U.S.A.
DULUTH
Sault Ste. Marie
St. Marys R.
Ottawa R.
MONTREAL
RIVER
OTTAWA
ST. LAWRENCE
Georgian Bay
LAKE HURON
LAKE MICHIGAN
Mississippi River
Kingston
TORONTO
LAKE ONTARIO
Oswego
HAMILTON
NIAGARA FALLS
Niagara R.
BUFFALO
L. St. Clair
St. Clair R.
DETROIT
Detroit R.
WINDSOR
LAKE ERIE
CHICAGO
CHICAGO SANITARY AND SHIP CANAL
LIMIT OF THE GREAT LAKES DRAINAGE BASIN
DEPARTMENT OF NORTHERN AFFAIRS AND NATIONAL RESOURCES
WATER RESOURCES BRANCH
GREAT LAKES-ST. LAWRENCE RIVER SYSTEM
SCALE OF MILES
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THE GREAT LAKES/WHAT ARE THEY LIKE?

There are six Great Lakes – Superior, Michigan, Huron, St. Clair, Erie, Ontario – about 100,000 square miles of water. If that sounds like a lot of water the amount of land that drains into the lakes is twice as large. This means that some 300,000 square miles, and many times that number of people, are affected by this huge network of connecting waterways, with lakes so big that looking out over their horizons is like looking out to sea.

In Canada the drainage area extends from the forest wilderness north of Lake Superior to the industrial hearts of Toronto and Hamilton and, in the United States, to Chicago, Detroit and Cleveland.

East and west it stretches from the watershed of the St Louis River which flows into Lake Superior near Duluth, Minnesota, to the upper reaches of its outlet to the sea, the St. Lawrence River near Kingston, Ontario.

The five outlet rivers of the Great Lakes system play an important part in water level changes. One way to appreciate this is to see the complex pattern of lakes and rivers on a map. Another way is to go up in a helicopter and look down on a world peopled by water and shipping. Here's how each river serves its lake.

- the St. Mary's River is Lake Superior's outlet into Lake Huron
- the St Clair River is Lake Huron's outlet into Lake St Clair
- the Detroit River is Lake St Clair's outlet into Lake Erie
- the Niagara River is Lake Erie's outlet into Lake Ontario
- the St. Lawrence River is Lake Ontario's outlet into the Atlantic Ocean

The Straits of Mackinac join Lake Michigan and Lake Huron but are not considered as an outlet river. The Straits are so wide and deep that there is no perceptible difference in water levels of the two lakes. They behave as one and are so treated in all hydraulic studies.

The International Boundary between Canada and the United States runs through all the Great Lakes (except Lake Michigan which lies wholly in the United States) and their connecting rivers. This means that data (information) on snow and rainfall, water levels and streamflow, must be collected, shared, and analysed by both countries to serve the total picture. Many of these studies are carried out jointly under a coordinating committee set up by agencies of both countries for this purpose. The International Joint Commission established under the Boundary Waters Treaty of 1909 recommends solutions to those joint problems related to water levels of boundary waters which the two governments refer to it. The Federal governments of Canada and the United States must approve of the proposed solutions for handling the boundary or international waters affected by these proposals. International cooperation is maintained also on scientific research conducted in the Great Lakes.

THE HOMEWORK THAT BEGAN A HUNDRED YEARS AGO

Patient men, mainly engineers, have been collecting records on Great Lakes water levels continuously for the past hundred years. Rain and snowfall record-keeping goes back almost as far. Measurement of discharges from the outlet rivers began more than sixty years ago and these measurements have been related to water levels data in such a way as to make it possible to compute discharges as far back as water level records have been kept.

These studies have built up to become part of a large fund of technical knowledge available to, and used by, Great Lakes engineers and administrators.

But even so, gaps remain. The most important practical gap is the lack of some method of predicting with accuracy what water levels will be in the future. Yet in spite of this gap in our knowledge the fact that we have almost a century of records of lake levels, lake outflows and rainfall, enables us to draw engineering conclusions about variations in water levels.

Weather observations by kytoon provide temperature-humidity-wind data to 1,000 ft.

WHERE DOES THE GREAT LAKES WATER COME FROM?

The Great Lakes, long ago, were filled by the melted ice and snow of the ancient great glaciers that covered northern North America.

Since those far-off days the lakes' main source of water has been the rain and snow falling on their surface and on the land draining into them.

The normal amount of water falling on the lakes and on the land draining to them is about 32 inches a year, but the average outflow, as measured in the outlet rivers, is about 10 inches. The difference between 32 inches of precipitation and 10 inches of river flow is made up of the water returned to the air by evaporation from lake and soil surfaces and by the "breathing" of trees, grasses, and crops.

Rain and snowfall on the drainage area varies erratically from year to year. The return of water to the atmosphere by evaporation is also quite variable year by year. The amount of water evaporated and transpired also changes widely from season to season and is highest in the summer and fall months. There are, therefore, considerable changes in inflow to the lakes but because of land freeze-up in the winter, melting snow in the spring and high evaporation and transpiration in summer and fall, a definite seasonal pattern is apparent.

WHY DO WATER LEVELS IN THE GREAT LAKES RISE AND FALL?

Water level changes on Lake Erie and Lake Michigan-Huron are caused in part by the limited discharge capacity of the Niagara, St Clair and Detroit Rivers.

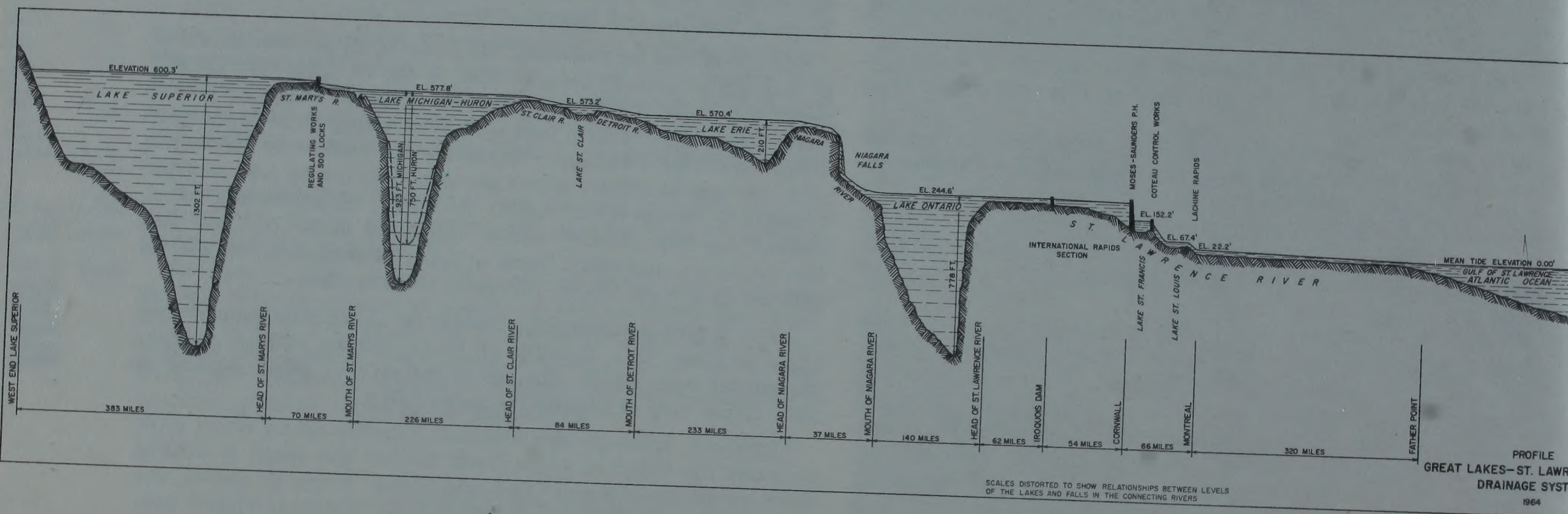
Storage of one foot of water on Lake Michigan-Huron would be enough to sustain average flow in the St Clair and Detroit rivers for about 75 days. Yet if the level of Michigan-Huron were raised or lowered a foot their flow would be changed only 10 per cent. So it becomes impossible for outflow to follow the wide changes in inflows which are smoothed out by lake storage. Changes in water levels caused by inflow variations will affect outflow for two years or more. The flows in the St Clair and Detroit rivers, and water levels of Lake Michigan-Huron will be affected by present inflows for many years to come.

To a degree conclusions reached for Lake Michigan-Huron apply to Lake Erie. Because of Erie's smaller surface, though, the period over which changes in inflow will affect outflow is only 20 per cent of that on the larger lakes.

Therefore, although the restricted capacity of an outlet river increases the range of water levels on the lake itself, it reduces them on all downstream lakes and rivers. It can be shown, for example, that to keep the levels of Lake Michigan-Huron con-

stant, it would be necessary at times to reverse the flow in the St Clair River and at other times increase the flow to triple the maximum. Alternatively, to keep the flow in the St Clair River constant would require a variation (called technically a "range of stage") on Lake Michigan-Huron of 8.4 feet – or 60 per cent greater than the maximum recorded range since 1900.

It is very difficult to disturb the delicate natural balance created over the years without causing adverse effects to lake-shore properties, water supply intakes, navigation and power production. Therefore the water levels of the lakes that are controlled (Lake Superior and Lake Ontario) follow quite closely the natural water level pattern with significant changes occurring only when it is obvious that high or low inflows will continue for some time into the future.



The Sault Ste. Marie Locks and control facilities at the head of St. Mary's River.

HOW DO THE GREAT LAKES DIFFER FROM OTHER SYSTEMS?

It is essential to recognize some of the large factors men must deal with in considering the control of the Great Lakes. And – if you are a resident of Montreal – how these factors bear on the water levels of Montreal Harbour. The Great Lakes and St. Lawrence River system is unique and differs from other river systems because of the sheer size of the Great Lakes.

Seasonal variations in Great Lakes water levels are due to phenomena that occur every year. Melting snow and low evaporation and transpiration during the spring months cause the lake levels to rise, usually reaching a maximum in early summer. High evaporation and transpiration during summer and fall cause a regular decrease in water levels. Due to the piling up and melting of snow, there is no regular pattern of water level changes in winter. This type of seasonal variation is apparent on all the tributary streams flowing into the Great Lakes.

Long-term variations are due to the large surface areas and restricted outlet capacities of the Great Lakes. This can result in the accumulation over the years of the effects of persistent rain and snow, some years too heavy, some years too light. Such a build-up means that average levels can remain above or below normal for many years, and that average seasonal changes are superimposed on a higher or lower base. This type of variation is very different from those observed on ordinary river systems which do not have as much water surface area. It also explains why the Great Lakes can be low when neighbouring rivers and lakes are high and vice versa.

DO GREAT LAKES WATER LEVELS FOLLOW ANY CYCLICAL PATTERN?

Long-term changes follow the highs and lows of rain and snowfalls. An analysis of about 100 years of records reveals that though there are many consecutive years of high or low rain and snow these are more a matter of chance than any predictable

Loaded freighter glides under the Thousand Islands International Bridge over the St. Lawrence Seaway, greatest inland shipping route in the world. Bridge links Canada and the United States at the borders of Ontario and New York.

cyclical causes. *Seasonal* changes do follow a cyclical pattern but depend so heavily on the weather that accurate predictions are still not possible.

When it is a matter of how much rain and snow will fall, where, and in what years, nature still reserves the right to take the big decisions.

IS THERE A TREND TOWARDS LOWER WATER LEVELS?

Analysis of rain and snowfall records of about 100 years indicates no trend to lower rain and snowfall on the Great Lakes basin. Engineers and meteorologists expect the same weather patterns to keep recurring – years when rain and snow is heavy and others when it is light. The fact that the highest recorded inflow occurred in 1951 and 1952 and the lowest in 1963 and 1964 would indicate no well-established trend in inflows.

There is one other natural factor that does cause trends in the water levels of the Great Lakes. The phenomenon is known as crustal movement. This is due to the recovery of the earth's crust after being pressed down by the glaciers several thousand years ago. This is proceeding at a faster rate to the north-east than in the south-west. This phenomenon causes the water level to fall with respect to the land at any point on the shoreline to the east or north of a lake outlet and to rise with respect to the land at any point to the south and west of a lake outlet. On Georgian Bay, for example, which is east and north of the St Clair River, the water level is falling with respect to the land by some 10 inches every 100 years. Whereas around Chicago, which lies west and south of the St Clair River, the water level is rising with respect to the land at a rate of about 3 inches in a century.

HOW DOES WATER STORAGE AFFECT THE LOW YEARS?

Of the four Great Lakes (if Lake St Clair is excluded and Michigan and Huron considered as one) two are completely controlled, Lakes Superior and Ontario. Lakes Michigan-Huron and Erie are not.

A basic principle of water management in the control of lakes is to store water during periods of ample water supply for use when the supply is low.

There are several limitations on the amount of water that may be stored. Two of the more important of these are storage space and the amount of water available for storage. On lakes the size of these in the Great Lakes system, it is obvious that storage space available is greater than can be filled and emptied in a few months.

It has taken over three years of below normal rain and snowfall to deplete the storage on the Great Lakes to present levels, and this has resulted in low levels and low outflows for the lakes not artificially regulated. The lakes which are regulated have been held higher than normal under these drought conditions.

HAS SETTLEMENT CHANGED THE GREAT LAKES WATER LEVELS?

Clearing the original forest, draining and cultivating the land, building cities and towns – these have all had their effects on the water balance. Yet these changes, extensive though they have been in settling and developing this region of Canada and the United States, appear to have had small influence on the total volume of water available for inflow.

The most important changes to Great Lakes levels have been brought about by engineering works – diversions, dredging, the operation of control structures. Yet even the effect of these is small compared to the effect of rain, snow, and evaporation.

HOW DO DIVERSIONS AFFECT GREAT LAKES LEVELS?

When levels are low one solution is to divert into the system water that is not being used or used fully elsewhere.

Three interbasin diversions operate in the Great Lakes – the Long Lac and Ogoki diversions that channel water from Hudson Bay tributaries into Lake Superior and are operated by the Ontario Hydro-Electric Power Commission, and the Chicago diversion that takes water from Lake Michigan and puts it into the Mississippi basin and is operated by the Sanitary District of Chicago.

The volume of water diverted into the Great Lakes by the Long Lac and Ogoki projects is roughly equivalent to three-tenths of an inch of rain a year on the entire Michigan-Huron basin, while the amount diverted out by the Chicago diversion is two-tenths of an inch of rain for the same period. This results in a net gain of about an inch to the water levels of Lakes Michigan-Huron and Erie.

When the flow of waters is re-channelled in this way certain large problems are usually encountered and solutions must be found.

Diversions into the Great Lakes improve low water levels but increase the risk of flooding unless they can be shut off when high water is expected. In the case of Lake Michigan-Huron this would require a forecast two to three years ahead because of the ever-present time relationship.

WHAT EFFECT HAS DREDGING OF OUTLET RIVERS HAD ON WATER LEVELS?

Lake Superior and Lake Ontario both have control works at their outlets. This question, then, relates only to Lake Michigan-Huron and Lake Erie.

To understand the effect or dredging in the St Clair and Detroit Rivers it must be remembered that the fall between Michigan-Huron and Erie is only seven to eight feet. Regardless of the amount of dredging in the St Clair and Detroit Rivers, the water level of Michigan-Huron could not be reduced by more than seven or eight feet.

The effect of dredging is to enlarge the outlet capacity. Water flow losses due to friction are thereby reduced and upstream water levels are lowered.

Water level records before the year 1900 are not good enough to be accurate guides to the effects of dredging in the St Clair and Detroit Rivers before that date. Since 1904 dredging has been carried on fairly continuously.

1904-1924 Dredging for gravel in the St Clair River and for navigation purposes, by the U.S. Corps of Engineers in the St Clair Delta. Estimated reduction in the water level of Lake Michigan-Huron as a result of these operations is from five to six inches.

1933-1937 Dredging by the U.S. Corps of Engineers to provide 25-foot navigation through the St Clair and Detroit Rivers. This operation is believed to have reduced the level of Michigan-Huron by two and a half to three and a half inches.

1960-1963 Dredging by the U.S. Corps of Engineers to provide 27-foot navigation through the St Clair and Detroit Rivers. Fall in levels estimated at one to one and a half inches.

These operations combined have reduced the level of Michigan-Huron by some figure between 8 and 11 inches.

The diversion of water from Lake Erie to Lake Ontario by way of the Welland Canal and DeCew Falls power plant tailrace and the New York Barge Canal, lowers the level of Lake Erie by some four and a half inches and of Michigan-Huron by about two inches.

Fixed structures can be placed in the St Clair and Niagara Rivers to restrict the flows and compensate for reduced water levels. Such compensating works, however, would cause levels to go higher than they otherwise would and so cause flooding in the event of future high inflow.

WHAT IS THE EFFECT OF REGULATING LAKES SUPERIOR AND ONTARIO?

Water levels and outflows on Lake Superior have been regulated under supervision of the International Joint Commission since August 1921.

The necessary dredging in the St Mary's River and construction of the control dam were accomplished very economically. The gates of the control dam are operated in such a way as to store water on the lake in years of high inflow so that during years when rain and snow are light the outflows can be kept higher than they would be if the dam were not there.

The equalizing effect of the large area and storage capacity on Michigan-Huron has absorbed the rapid variations in discharge from Lake Superior and distributed the effects over longer periods.

This has resulted in downstream lakes being slightly higher or lower than they would have been if Lake Superior had not been regulated. For example, the maximum increase was six inches on Lake Huron and the maximum decrease in levels caused by Lake Superior regulation was three and one-half inches. The effect on the lower lakes was somewhat smaller.

Lake Ontario has been regulated under supervision of the International Joint Commission since July 1958. Dredging was undertaken and control dams constructed as part of the St Lawrence Seaway and Power Project. The purpose of the regulation is to decrease the frequency of high and low water levels on the lake for the benefit of lakeshore residents and navigation, and to increase the winter flows in the St Lawrence for the benefit of hydro electric installations without adding to the frequency of either high or low levels in the St Lawrence River near Montreal.

Compared to the regulation of Lake Superior, regulating Lake Ontario is very difficult. The shoreline of Lake Ontario is much more developed. Instead of having a huge water surface such as Lake Michigan-Huron downstream to absorb large short-term increases in outflow, Lake Ontario has Lake St. Louis and Montreal Harbour where such flow changes cause wide fluctuations in water levels.

Dampening effects of the upper Lakes, however, cause the Niagara River inflow to Lake Ontario to vary slowly and regularly within a relatively narrow range. It is possible, then, to increase Lake Ontario's levels when those of the upper lakes are falling and to lower the levels of Lake Ontario when the upper lakes are rising.

However, since the regulated lakes have been subjected to low rainfall, and since their outflows have to be maintained to meet downstream requirements, their storages are also deficient. This is the present situation with respect to Lake Ontario.

There was an opportunity in the spring of 1964 to store additional water on Lake Ontario for use later in the year and the International St Lawrence River Board of Control (under the International Joint Commission) took advantage of this opportunity after consulting the operating authorities on the river.

On the other hand because of more favourable storage conditions on Lake Superior the International Lake Superior Board of Control is releasing extra water to ease conditions downstream.

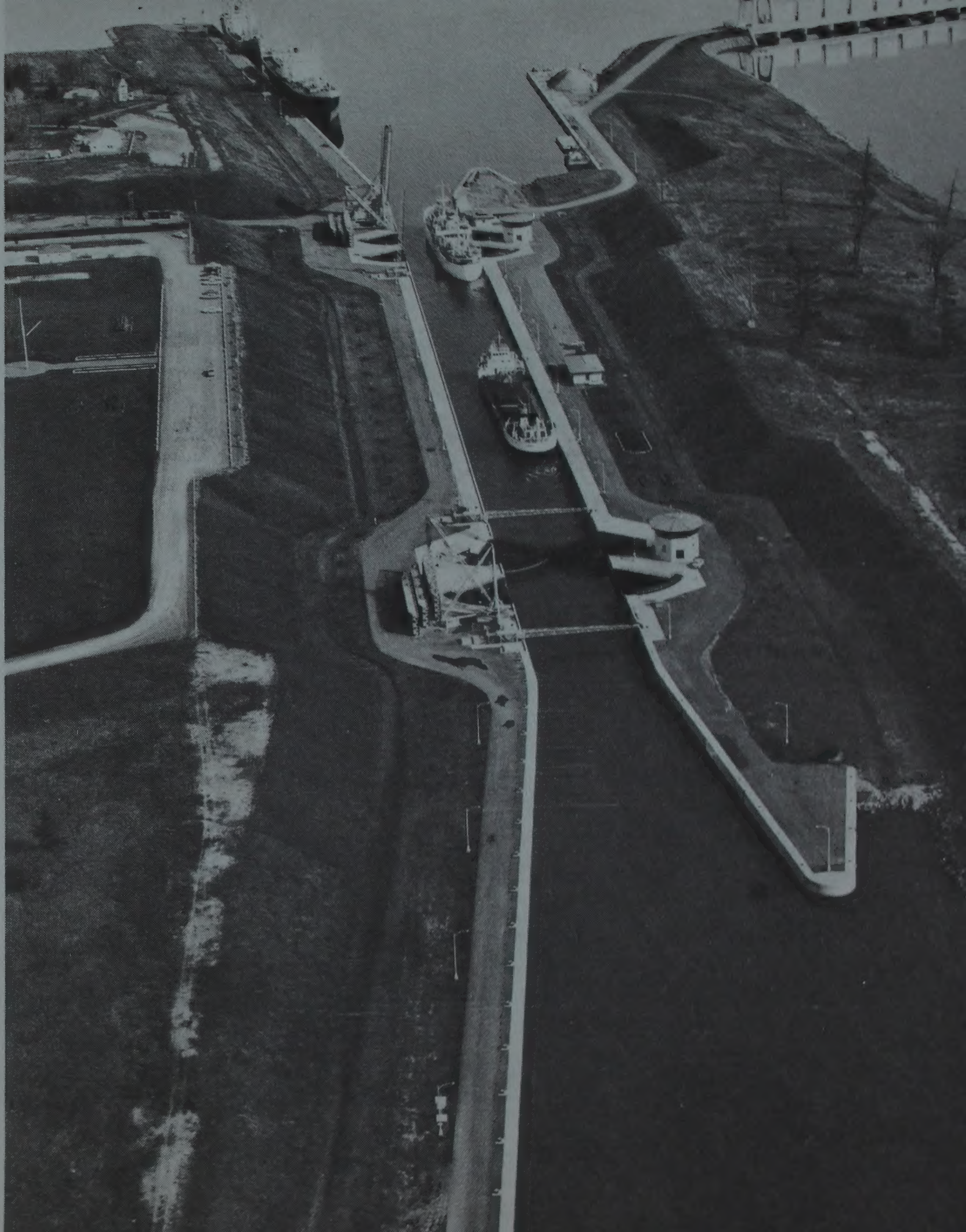
Time factors are important to storage and consequently to the levels of the Great Lakes. To illustrate the point, if the outflow from Lake Superior were increased by a constant amount, it would require almost three years for one-half of this increase to reach the St. Lawrence River. Why? Because a large volume of water is needed to raise the water levels of Lakes Michigan-Huron and Erie to increase their outflows.

It would require, for example, almost one *million million* gallons of water to raise Lake Michigan-Huron sufficiently so that it could discharge an additional 2000 cubic feet per second of water.

This additional flow, if transferred to the St Lawrence River, would raise Lake St Louis and the levels of Montreal Harbour by about an inch.

These are tremendous forces with which we are dealing and changes in them persist in the system for many years. You cannot turn nature on and off like a light switch.

Iroquois Lock on the St. Lawrence Seaway. Last in a series of seven that allow freighters to travel up river beyond Montreal into Lake Ontario.



ARE THERE ANY EASY ANSWERS?

The problem of low water levels on the Great Lakes are intensely complicated. Even the three possible solutions – diversion, release of storage on Lake Superior, wider regulation of the lakes – are each subject to reservation. Diversion to the Great Lakes could make conditions of high water worse until weather forecasters can look farther ahead. Release of storage on Lake Superior while assisting lake levels in Michigan-Huron provides no immediate relief for Montreal Harbour or Lake St Louis. Regulation of all lakes may be the best initial approach.

Considering diversion first, the consumptive demands of the Canadian provinces and American states bordering on the Great Lakes may soon reach intensity that financing such a diversion would be practicable.

Yet two strong words of caution should be said – the difficulty of predicting rain and snowfall on the Great Lakes and the two to three year time lag in run-off throughout the system. A danger might exist of diverting water into the Great Lakes followed by a subsequent year of heavy rain and snow. Taken together they might cause flood conditions that it would then be too late to control.

A second possible solution to low water levels might be to accelerate the release of storage on Lake Superior. But again the effects of timing, and other factors, with the present limitations on long-range weather forecasting, would strongly influence the course of action.

A third possible solution is regulation of all the lakes. Two only of the four Great Lakes are regulated now. We should study what might be done with the natural supplies through coordinated regulation of the four lakes before adding water to the system.

This proposal is being considered by the federal governments of Canada and the United States. If the technical problems can be solved this would enable larger amounts of storage to be set aside at the beginning of dry periods to maintain flows through times of low lake levels and water shortage. One of the most difficult problems would be the development of improved long-term weather forecasts.

Water levels, crucial as they are for shipping, are only part of an ever larger problem, the use of water as water. No national resource is more essential nor has a more versatile range of uses. Water? Try for a day to live without it.

When the immediate problem of easing the situation of low water levels on the Great Lakes has passed, a larger one remains – the need for Canadians everywhere to work out, through governments and private agencies, how these multiple water uses can best be coordinated within the available supply. This is a task so big and so pressing that it requires the best efforts of three levels of government working together.

What is the Federal Government's responsibility? It is the government's responsibility in the national interest to give leadership in the research, and planning of water resources by working in partnership with provincial authorities.

The development of an adequate research programme and a national water management policy is a priority to occupy Canadians for the next generation. We have had such a policy for many years but to meet the demands of a growing population and a dynamic economy it must be revised and sharpened.

Is this all that is needed against low water levels? Not quite. So long as rain and snow continue to fall without reference to the convenience of mankind, a percentage of Canadians will continue to be occupied trying to lengthen the time span in which they can confidently predict the weather.

Canada: WaterResources Branch
Dept. of Northern Affairs and
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